# Herring Stock Estimates from Diving Surveys of Spawn for the North Coast of British Columbia in 1982

J. F. Schweigert and C. W. Haegele

Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

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# HERRING STOCK ESTIMATES FROM DIVING SURVEYS OF SPAWN FOR THE NORTH COAST OF BRITISH COLUMBIA IN 1982

by

J. F. Schweigert and C. W. Haegele

Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

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## ABSTRACT

Schweigert, J. F. and C. W. Haegele. 1984. Herring stock estimates from diving surveys of spawn for the North Coast of British Columbia in 1982. Can. MS Rep. Fish. Aquat. Sci. 1795: 43 p.

Divers surveyed and sampled major 1982 herring spawns in Statistical Areas 3 to 5. Spawner biomass was estimated at 5700 tonnes, which agreed closely with prespawning echosounder estimates, but was considerably lower than the 19,500 to 29,000 tonnes estimated with population models. The low estimated spawner biomass supports the decision to close the sac-roe fishery in Chatham Sound from 1979 through 1983 and in Porcher Island from 1982 through 1983.

Key words: Pacific herring, spawn, diver survey, stock assessment

## RÉSUMÉ

Schweigert, J. F. and C. W. Haegele. 1984. Herring stock estimates from diving surveys of spawn for the North Coast of British Columbia in 1982. Can. MS Rep. Fish. Aquat. Sci. 1795: 43 p.

Des plongeurs ont étudié et échantillonné les grands frais de hareng de 1982 dans les zones statistiques 3, 4 et 5. La biomasse a été évaluée à 5,700 t, ce qui se rapproche beaucoup des estimations effectuées par écho-sondeur avant la fraie, mais est considérablement inférieure aux 19,500 à 29,000 t déterminées à l'aide de modèles démographiques. La faible biomasse estimative de reproducteurs appuie la décision d'interdire la pêche du hareng plein dans le passage Chatham, de 1979 à 1983, et dans l'île Porcher, de 1982 à 1983.

Mots-clés: hareng du Pacifique, frai, levé en plongée, évaluation du stock

## INTRODUCTION

Stocks of herring (Clupea harengus pallasi) on the North Coast (Statistical Areas 3 to 5) of British Columbia supported substantial reduction fisheries from the 1930s to the collapse of the stocks in 1967. Catches from 1946 to 1967 averaged 25,000 tonnes and stocks were estimated to have averaged 70,000 tonnes for the period 1951 to 1970 (Hourston 1981). Between 1967 and 1970 a food and bait fishery continued to operate in Browning Entrance and an average of 1500 tonnes was landed annually. From 1971 to 1981, a sac-roe fishery as well as the Browning Entrance food and bait fishery operated on the North Coast and an average of 5300 tonnes was landed annually.

In 1978, a roe fishery catch of 8200 tonnes was anticipated for the North Coast; however, because of unexpectedly low echosounder estimates on the grounds, only 4400 tonnes were taken (Webb et al. 1980). There was concern by fishery managers and scientists that stock estimates, based primarily on Fishery Officer spawn report data, were unrealistically high for the North Coast, so a diving survey was conducted in 1979 in Chatham Sound (lower Area 3 and upper Area 4) to estimate egg deposition. Estimates from this survey were $8.0 \times 10^{11}$ eggs (Haegele and Miller 1979), which is approximately equivalent to 8000 tonnes of spawning fish, and this was considered below the minimum desired escapement for Chatham Sound. No sac-roe fishery was permitted in the year of the survey and Chatham Sound remained closed pending further assessment. In 1982, the remainder of the North Coast was also closed to the sac-roe fishery because of apparent low stock abundance and poor recruitment of the 1978 and 1979 year classes (Chalmers 1982). The North Coast remained closed to sac-roe fishing in 1983. To determine whether the closures were justified and to obtain an estimate of stock size that could be compared to other and future assessments, a diving survey of herring spawns was conducted in 1982. This survey is the subject of this report.

## METHODS

Herring spawns were sampled by SCUBA divers using a two-stage sampling design. Transects perpendicular to the shore were the primary sampling unit and 0.50 $m^2$ quadrats sampled along the transect were the secondary sampling unit. Samples consisted of the attached or rooted vegetation, and the eggs adhering to it, within the quadrat. These samples, after collection, were separated by vegetation classes into fractions, which were then weighed. A weighed subsample of each fraction was preserved for subsequent egg enumeration. Eggs on the bottom substrate were estimated from diver estimates on layers of eggs and percent of bottom covered by eggs [1 layer of eggs = $3.4 \times 10^5$ eggs$\cdot m^{-2}$ (Haegele et al. 1979)] and added to eggs on vegetation. For each quadrat the layers of eggs on vegetation and the percent cover of vegetation were estimated by divers and the depth at each sample site was recorded and later corrected to Chart Datum from water levels observed at Prince Rupert (Tides and Currents, Institute of Ocean Sciences, Sidney, B.C.).

Transects were established at approximately equal intervals and marked with gillnet leadline. Samples were collected also at equal intervals along transects. Based on preliminary analysis of results from studies in the Strait of Georgia, the optimal level of sampling was a transect density of 2.5 transects$\cdot km^{-1}$ and 5 samples per transect. In this survey transect density was 2.4 transects$\cdot km^{-1}$ and an average of 6.1 samples (n = 79, S.D. = 3.3) per transect were taken. The mean egg density (eggs$\cdot m^{-2}$) and 95% confidence interval were calculated assuming unequal primary units (transect lengths). This estimator weights the within transect means by the transect length to determine an overall mean for the spawn (Schweigert et al. 1984).

The inner and outer edge of spawns were determined from measurements along transects and the end of spawns beyond the outer transects were determined on exploratory dives. This information and the depth at sample sites were plotted on maps of shoreline vegetation at a scale of 1:6000 (Haegele and Hamey 1982a,b). The boundaries of the spawn and 2 m depth intervals were contoured using this information. The area of spawn between 2 m depth contours was measured on a micro-computer graphics tablet. Spawner biomass (tonnes) was estimated as the product of spawn area, egg density and $10^{-8}$, which assumes 200 eggs$\cdot g^{-1}$ female weight (Hay 1985) and a 1:1 sex ratio. Egg distribution by 2 m depth intervals was estimated as the product of spawn area and mean eggs$\cdot m^{-2}$ for quadrat samples obtained within the depth stratum.

Fishery Officers assessed the spawns independently from divers, recording length, average width, and average layers of eggs (Chalmers 1982). An echosounder estimate of herring biomass was made from a charter seine vessel and from Fishery Patrol vessels.

## RESULTS

Ten spawns were surveyed by divers on the North Coast in 1982. Locations of spawns, transect positions and quadrat locations are shown in Figs. 1 to 11. Sampling information, egg density and spawner biomass estimates are given for individual spawns, major geographical areas, and the entire North Coast in Table 1.

## BIOMASS ESTIMATES

### Chatham Sound

There were four spawns surveyed by divers in Chatham Sound. Spawning progressed from north to south, beginning on March 27 in Port Simpson and ending April 4 in Big Bay. In Port Simpson (Fig. 2) two small patches of spawn were combined for analysis and this spawn was deposited by 77 tonnes of herring. Around the Flat Top Islands (Fig. 3) 220 tonnes spawned. The spawn

in Pearl Harbor was continuous with spawn along Burnt Cliff Island and the small islands adjacent to Burnt Cliff Island (Fig. 3). Together, this spawn was produced by 1553 tonnes. In Big Bay 1503 tonnes spawned between Beletti and Shattock points (Fig. 4). The sum for individual spawns was 3353 tonnes of spawners. Combining the data for all spawns, the estimate was for 3505 tonnes.

North Porcher Island

On North Porcher Island, two spawns, deposited between April 4 to 10, were surveyed. The Hunt Inlet spawn (Fig. 6) was deposited by 315 tonnes, the Hunt-West (Fig. 7) spawn by 46 tonnes. The sum of these two estimates was 361 tonnes, the estimates for the combined data was 386 tonnes for North Porcher Island.

Kitkatla Inlet

In Kitkatla Inlet there were three waves of spawn. Herring spawned from March 16 to 20 in Dries Inlet, from April 4 to 10 on Ness Islands and in Freeman Passage, and on April 18 on Billy Islands. Dries Inlet spawn (Fig. 8) was deposited by 447 tonnes. Around Ness Islands (Fig. 9) an estimated 271 tonnes spawned. The Freeman Passage spawn (Fig. 10) was the largest in Kitkatla Inlet and was deposited by 823 tonnes. The late spawn on Billy Islands (Fig. 11) was the smallest and was deposited by 156 tonnes. The Kitkatla Inlet spawner biomass was estimated at 1966 tonnes for combined data and the sums of individual spawns produced an estimate of 1697 tonnes.

SPAWN DISTRIBUTION

Mean percent cover of vegetation, layers of eggs and egg density ($eggs \cdot m^{-2}$) were highest in the +2 to 0 m depth interval, declining with shallower and deeper depths (Fig. 12). However, only for Chatham Sound were the differences between depth intervals consistently significant. Between locations, only percent cover and layers in the 0 to -2 m depth interval were significantly different.

Spawn in Chatham Sound was deposited quite shallow, 81% of the area of spawn was above Chart Datum and 95% of the eggs were deposited above Chart Datum (Tables 2, 3; Figs. 13, 14). Spawn on the north shore of Porcher Island was deeper, 80% of the area of spawn was below Chart Datum, however due to low egg density in deeper water, 50% of the eggs were deposited above Chart Datum. In Kitkatla Inlet spawn was deposited to the greatest depth, to 10 m below Chart Datum. However, because of the considerable amount of shallow spawn in Dries Inlet, 42% of the area of spawn and 52% of the eggs were above Chart Datum.

## FISHERY OFFICER SPAWN SURVEYS

Fishery Officers located and surveyed most of the spawns surveyed by divers, except spawns on northern Porcher Island. In addition, Fishery Officers located and surveyed spawns in Portland Inlet. Fishery Officers generally reported on longer spawns in several patches. The results of the Fishery Officer spawn survey are compared to results from the diving survey in Table 4. For spawns where dual surveys were conducted, estimates of length were generally similar, estimates of spawn area by Fishery Officers were lower than by divers, and layers of eggs were estimated higher by Fishery Officers.

# DISCUSSION

## SPAWN SURVEY COMPARISON

In Chatham Sound, where 81% of the spawn area was found by divers to be above Chart Datum, Fishery Officer reports were for 71% of the area measured by divers. In Kitkatla Inlet, where 42% of the spawn area was found by divers to be above Chart Datum, Fishery Officers reported 27% of the area measured by divers. The mean tide for Prince Rupert in April 1982 was 3.9 m above Chart Datum. Hence, it would appear that Fishery Officers were unable to successfully determine the presence of spawn that was deeper than about 3 m below mean tide level. The survey techniques available to Fishery Officers, visual inspection from the water surface and grappling, appear not to be suitable for determining the presence of deeper spawn. Estimates of egg layers by Fishery Officers were higher than estimates by divers by 2 and 4 times for Chatham Sound and Kitkatla Inlet, respectively. Egg layer estimates by Fishery Officers were most likely made from samples obtained in the intertidal zone, where egg layers were greatest (Fig. 12).

Along some shorelines, Fishery Officers reported spawn where none was found by divers. Where spawn was found by divers, the length estimates by Fishery Officers were generally lower. Patchiness of spawn deposition was likely the explanation for both. When adjacent diving transects had spawn, it was assumed that spawn was continuous between them. If two successive diving transects had no spawn, then spawn was assumed to have ended. Hence, if spawn was patchy, then the diving survey could miss small spawns and, alternately, bare patches in larger spawns could remain undetected. Fishery Officer survey techniques, where the observer travels parallel to the shore, may be more amenable for detecting such discontinuities. Overall, however, length estimates from dual spawn surveys were similar (27.7 km vs 29.8 km).

## STOCK ESTIMATE COMPARISONS

The stock estimate for areas surveyed on the North Coast was for 5659 tonnes from the diving survey. This did not include Portland Inlet, where Fishery Officers reported 2.3 ha of spawn, which accounted for 3% of the total area of spawn reported by them. Adjusting the diving survey estimate by this factor, 5829 tonnes for the entire North Coast are estimated. The 1982 echosounder estimate was between 5300 and 6200 tonnes (Chalmers 1982). However, Chalmers speculates that early spawning fish in Kitlatla Inlet were not included in the echosounder estimate. He estimates these earlier spawners to have been 1800 to 2200 tonnes, but the early Dries Inlet spawn was found from the diving survey to have been deposited by only 447 tonnes.

Stock assessment models used for B.C. herring produced considerably higher stock estimates than the diving survey (Stocker et al. 1983). Hourston's method estimated 1982 spawner biomass at 19,500 tonnes. This method uses spawn survey data collected by Fishery Officers to calculate egg deposition and, from this, spawner biomass. An "egg survival factor" is used to compensate for under-reporting of spawn (factors of 0.33, 0.67, and 1.00 were used for the North Coast). The high stock estimate by the Hourston method was probably in part due to the high estimate of egg layers. The difference in eggs$\cdot m^{-2}$ between 1 layer and 3 layers (diver versus fishery officer estimate) on eelgrass at average (60) percent cover is 2.2 fold (Haegele et al. 1979). The age-structured model estimated the biomass of 3-yr-old and older fish at 29,000 tonnes (variable assumption) and the surplus production model estimated 20,000 tonnes (variable q). Since the estimates from the latter two models include all 3-yr-old and older fish, some of which may not have recruited, these estimates would tend to be higher. Both of these models also use the Fishery Officer spawn survey data (length and intensity) and the long, but narrow, spawns in Portland Inlet and the inflated estimate of egg layers may have contributed to the high stock estimates. Hence, some modification of the stock assessment models may be anticipated to calibrate them more closely with the more accurate escapement estimates that have been obtained by directly censusing egg depositon with diving surveys.

## MANAGEMENT IMPLICATIONS

The management strategy for British Columbia herring fisheries prior to 1983 was to allow the harvest of stocks that were surplus to a desired escapement (Hourston 1981). Since 1983 the harvesting strategy has been to harvest 20% of the forecast biomass (Stocker et al. 1983). The following discussion is based on the management strategy in place at the time of the spawn survey.

The spawner requirement for Chatham Sound had been set at 9072 tonnes for 1982 (Hourston 1981). The diving survey estimated 3353 tonnes in 1982. In 1979, a diving survey estimated 8000 tonnes (Haegele and Miller 1979). The 1979 estimate may be high because of the method used to estimate egg density. Rather than actual egg enumeration, as in 1982, egg densities were predicted from diver observations in 1979. Although layers of eggs were significantly higher ($P = 0.005$) in 1979 (1.5 layers) than in 1982 (0.9 layers), they were not sufficiently higher to account for the difference in egg density which was

estimated at $7.30 \times 10^5$ eggs$\cdot m^2$ in 1979 and at $2.10 \times 10^5$ eggs$\cdot m^2$ in 1982. As well, area of spawn was greater in 1982 than in 1979 (167.2 ha vs 110.3 ha). However, there probably was a moderate decline in stocks from 1979 to 1982 and the 1982 estimate is lower than the desired escapement. Hence, the decision by managers to close the sac-roe fishery in Chatham Sound between 1979 and 1983 appears to have been well justified.

The spawner requirement for Porcher Island, which includes spawns on the north cost of Porcher Island and in Kitkatla Inlet, had been set at 9072 tonnes (Hourston 1981) for 1982. The estimate from the diving survey was for 2352 tonnes. Hence, the 1982 to 1983 sac-roe fishery closure in this area appears to have been the proper management decision.

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Table 1. Length, area, egg density, and spawner biomass estimates for individual spawns, sections and the entire North Coast for spawns surveyed by divers in 1982.

| Location | Length (km) | Av. transect length (m) | Area (ha) | No. of transects | No. of samples | Eggs $\times m^{-2} \times 10^{-3}$ (95% C. I.) | Tonnes of spawners (95% C. I.) |
|---|---|---|---|---|---|---|---|
| Port Simpson | 1.0 | 36 | 4.07 | 5 | 21 | 188.7 (8.8-368.6) | 77 (4- 150) |
| Flat Top Islands | 1.2 | 60 | 6.32 | 4 | 19 | 348.3 (14.4-682.2) | 220 (9- 431) |
| Pearl Harbour | 7.5 | 89 | 76.62 | 15 | 92 | 202.7 (127.9-277.6) | 1553 (980-2127) |
| Big Bay | 4.4 | 153 | 80.22 | 6 | 52 | 187.4 (68.6-306.3) | 1503 (550-2457) |
| Chatham Sound | 14.1 | 89 | 167.23 | 30 | 184 | 209.6 (143.3-276.0) | 3505 (2395-4616) |
| Hunts Inlet | 4.0 | 51 | 13.57 | 10 | 52 | 231.9 (60.6-403.2) | 315 (82- 547) |
| Hunts West | 1.8 | 34 | 6.27 | 5 | 20 | 73.7 (-64.2-211.6) | 46 (0- 133) |
| North Porcher | 5.8 | 46 | 19.84 | 15 | 72 | 194.5 (51.5-337.4) | 386 (102- 669) |
| Dries Inlet | 4.0 | 164 | 70.53 | 7 | 56 | 63.4 (-9.0-135.9) | 447 (0- 959) |
| Ness Islands | 3.0 | 47 | 14.87 | 6 | 26 | 182.2 (36.3-328.2) | 271 (54- 488) |
| Freeman Passage | 4.8 | 87 | 48.80 | 13 | 89 | 168.6 (34.2-303.1) | 823 (167-1479) |
| Billy Islands | 1.8 | 77 | 8.70 | 8 | 55 | 179.1 (65.8-292.5) | 156 (57- 255) |
| Kitkatla Inlet | 13.6 | 92 | 142.90 | 34 | 226 | 137.6 (76.6-198.6) | 1966 (1095-2838) |
| North Coast | 33.5 | 82 | 329.97 | 79 | 482 | 171.5 (127.9-215.0) | 5659 (4220-7094) |

Table 2. Area of spawn (ha) by depth interval for 1982 North Coast herring spawns surveyed by divers.

| Location | Depth interval (m above or below Chart Datum) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | +4to+2 | +2to0 | 0to-2 | -2to-4 | -4to-6 | -6to-8 | -8to-10 | +4to-10 |
| Chatham Sound | | | | | | | | |
| Port Simpson | 0.49 | 2.39 | 1.19 | | | | | 4.07 |
| Flat Top Islands | 0.81 | 4.06 | 1.45 | | | | | 6.32 |
| Pearl Harbour | 17.54 | 45.17 | 7.11 | 3.72 | 3.08 | | | 76.62 |
| Big Bay | 26.58 | 38.72 | 14.92 | | | | | 80.22 |
| All Chatham | 45.42 | 90.34 | 24.67 | 3.72 | 3.08 | | | 167.23 |
| North Porcher | | | | | | | | |
| Hunts Inlet | 0.88 | 2.64 | 5.29 | 3.77 | 0.99 | | | 13.57 |
| Hunts-west | | 0.32 | 1.37 | 2.55 | 2.03 | | | 6.27 |
| All Porcher | 0.88 | 2.96 | 6.66 | 6.32 | 3.02 | | | 19.84 |
| Kitkatla Inlet | | | | | | | | |
| Dries Inlet | 2.82 | 40.72 | 19.46 | 7.53 | | | | 70.53 |
| Ness Islands | 0.50 | 5.64 | 8.33 | 0.40 | | | | 14.87 |
| Freeman Pass | 3.15 | 6.93 | 10.60 | 10.84 | 10.84 | 5.44 | 1.00 | 48.80 |
| Billy Islands | 0.10 | 0.26 | 2.01 | 5.42 | 0.69 | 0.22 | | 8.70 |
| All Kitkatla | 6.57 | 53.55 | 40.40 | 24.19 | 11.53 | 5.66 | 1.00 | 142.90 |
| North Coast | 52.87 | 146.85 | 71.73 | 34.23 | 17.63 | 5.66 | 1.00 | 329.97 |

Table 3. Estimates of egg density and spawner biomass by depth interval for 1982 North Coast herring spawns surveyed by divers.

| Location | Depth interval | Area (ha) | Eggs.$10^{-3}$.$m^{-2}$ (95% C.I.) | Tonnes of spawners (95% C.I.) |
|---|---|---|---|---|
| Chatham Sound | +4 to +2 | 45.42 | 237 (153 to 321) | 1076 (694 to 1458) |
| | +2 to 0 | 90.34 | 252 (188 to 316) | 2277 (1698 to 2855) |
| | 0 to -2 | 24.67 | 48 (10 to 86) | 118 (25 to 212) |
| | -2 to -4 | 3.72 | 115 (9 to 221) | 43 (3 to 82) |
| | -4 to -6 | 3.08 | 126 (-38 to 290) | 39 (0 to 89) |
| North Porcher | +4 to +2 | 0.88 | 402 (70 to 734) | 35 (6 to 65) |
| | +2 to 0 | 2.96 | 385 (13 to 757) | 114 (4 to 224) |
| | 0 to -2 | 6.66 | 133 (49 to 217) | 89 (33 to 145) |
| | -2 to -4 | 6.32 | 97 (21 to 173) | 61 (13 to 109) |
| | -4 to -6 | 3.02 | 3 (0 to 6) | 1 (0 to 2) |
| Kitkatla Inlet | +4 to +2 | 6.57 | 161 (65 to 257) | 106 (43 to 169) |
| | +2 to 0 | 53.55 | 196 (54 to 338) | 1050 (289 to 1810) |
| | 0 to -2 | 40.40 | 116 (52 to 180) | 469 (210 to 727) |
| | -2 to -4 | 24.19 | 65 (33 to 97) | 157 (80 to 235) |
| | -4 to -6 | 11.53 | 212 (98 to 326) | 244 (113 to 376) |
| | -6 to -8 | 5.66 | 319 (-69 to 707) | 181 (0 to 400) |
| | -8 to -10 | 1.00 | 401 (-401 to 1203) | 40 (0 to 120) |

Table 4. Comparison of diving survey and Fishing Officer spawn survey results for 1982 herring spawns on the North Coast of British Columbia.

| Location | Transects | Diver | | | Fishery Officer | | | F.O.-Div-1 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Length (m) | Area (ha) | Layers | Length (m) | Area (ha) | Layers[a] | Length | Area | Layers |
| Portland Inlet | | | | | | | | | | |
| Hastings Arm | - | | No survey | | 1000 | 0.50 | 0.2 | - | - | - |
| | - | | No survey | | 2500 | 0.25 | 0.1 | - | - | - |
| | - | | No survey | | 300 | 0.03 | 0.7 | - | - | - |
| | - | | No survey | | 3500 | 0.35 | 0.4 | - | - | - |
| | - | | No survey | | 7300 | 1.13 | 0.2 | - | - | - |
| Alice Arm | - | | No survey | | 150 | 0.03 | 0.1 | - | - | - |
| | - | | No survey | | 300 | 0.09 | 0.3 | - | - | - |
| | - | | No survey | | 150 | 0.08 | 0.3 | - | - | - |
| | - | | No survey | | 150 | 0.08 | 0.2 | - | - | - |
| | - | | No survey | | 25 | 0.03 | 0.5 | - | - | - |
| | - | | No survey | | 25 | 0.01 | 0.1 | - | - | - |
| | - | | No survey | | 150 | 0.08 | 0.3 | - | - | - |
| | - | | No survey | | 30 | 0.02 | 0.5 | - | - | - |
| | - | | No survey | | 20 | 0.01 | 0.5 | - | - | - |
| | - | | No survey | | 20 | 0.01 | 0.5 | - | - | - |
| | - | | No survey | | 80 | 0.24 | 0.3 | - | - | - |
| | - | | No survey | | 150 | 0.08 | 0.3 | - | - | - |
| | - | | No survey | | 1250 | 0.76 | 0.4 | - | - | - |
| Chatham Sound | | | | | | | | | | |
| Port Simpson 1 | - | - | - | - | 100 | 0.15 | 1.0 | - | - | - |
| | - | - | - | - | 300 | 0.15 | 1.4 | - | - | - |
| | - | - | - | - | 200 | 0.40 | 2.2 | - | - | - |
| | - | - | - | - | 50 | 0.03 | 2.0 | - | - | - |
| | B1-B3 | 680 | 1.90 | 1.9 | 650 | 0.73 | 1.8 | 0.96 | 0.38 | 0.95 |
| Port Simpson 2 | - | - | - | - | 300 | 0.30 | 2.6 | - | - | - |
| | - | - | - | - | 300 | 0.30 | 1.0 | - | - | - |
| | - | - | - | - | 600 | 0.60 | 1.6 | - | - | - |
| | - | - | - | - | 600 | 0.90 | 0.6 | - | - | - |
| | B4,B5 | 320 | 2.17 | 0.8 | 1800 | 2.10 | 1.2 | 5.63 | 0.97 | 1.50 |
| Flat Top Is. | B1-B4 | 1200 | 6.32 | 1.0 | 900 | 1.80 | 2.7 | 0.75 | 0.28 | 2.70 |
| Pearl Harbour | B1,B2 | 640 | 2.55 | 0.8 | 1600 | 4.80 | 2.1 | 2.50 | 1.88 | 2.63 |
| | B3,B4 | 700 | 4.33 | 0.7 | 500 | 1.50 | 4.0 | 0.71 | 0.35 | 5.71 |
| | B5,B6 | 850 | 9.47 | 0.6 | 500 | 2.00 | 2.9 | 0.59 | 0.21 | 4.83 |
| | (B7) | 180 | 1.32 | 2.7 | 250 | 0.75 | 3.1 | 1.39 | 0.57 | 1.15 |
| | B7-B9 | 2100 | 26.98 | 1.5 | 1900 | 7.60 | 3.0 | 0.90 | 0.28 | 2.00 |
| | B11 | 250 | 2.02 | 1.4 | 300 | 0.30 | 1.6 | 1.20 | 0.15 | 1.14 |
| | (B11) | 320 | 1.32 | 1.4 | 600 | 1.20 | 2.7 | 1.88 | 0.91 | 1.93 |

Table 4 (cont'd)

| Location | Transects | Diver | | | Fishery Officer | | | F.O.-Div-1 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Length (m) | Area (ha) | Layers | Length (m) | Area (ha) | Layers[a] | Length | Area | Layers |
| Pearl Harbour (cont'd) | B10,B12 | 600 | 9.61 | 0.9 | 800 | 2.40 | 1.8 | 1.33 | 0.25 | 2.00 |
| | B13,B14 | 800 | 5.65 | 1.0 | 600 | 3.00 | 3.4 | 0.75 | 0.53 | 3.40 |
| | (B14) | 500 | 9.32 | 1.0 | 500 | 5.00 | 3.2 | 1.00 | 0.54 | 3.20 |
| | B15 | 560 | 4.05 | 0.6 | 800 | 2.40 | 2.9 | 1.43 | 0.59 | 4.83 |
| | B1-B15 | 7500 | 76.62 | 1.0 | 8350 | 30.95 | 2.9 | 1.11 | 0.40 | 2.90 |
| Big Bay | B1 | 320 | 5.85 | 0.4 | 600 | 12.00 | 2.4 | 1.88 | 2.05 | 6.00 |
| | (B1) | 540 | 7.65 | 0.4 | 1200 | 4.80 | 2.7 | 2.22 | 0.63 | 6.75 |
| | B2-B4 | 1900 | 49.95 | 1.4 | 1600 | 29.00 | 3.9 | 0.84 | 0.58 | 2.79 |
| | (B4) | 310 | 9.15 | 0.7 | 600 | 3.60 | 3.0 | 1.94 | 0.39 | 4.29 |
| | B5 | 1050 | 5.88 | 0.5 | 1400 | 3.50 | 2.9 | 1.33 | 0.60 | 5.80 |
| | B6 | 280 | 1.74 | 1.1 | 2000 | 30.00 | 0.3 | 7.14 | 17.24 | 0.27 |
| | B1-B6 | 4400 | 80.22 | 1.2 | 7400 | 82.90 | 2.2 | 1.68 | 1.03 | 1.83 |
| North Porcher Hunts Inlet | B1-B11 | 4000 | 13.57 | 0.9 | No report | | | - | - | - |
| Hunts - West | B1-B5 | 1800 | 6.27 | 0.3 | No report | | | - | - | - |
| Kitkatla Inlet Dries Inlet | B1-B4 | 1680 | 36.43 | 0.7 | (2000) | 17.54 | 2.0 | (1.19) | 0.48 | 2.86 |
| | B5,6,8 | 2320 | 34.10 | 0.5 | 137 | 0.63 | 3.8 | 0.06 | 0.02 | 7.60 |
| | - | | No spawn | | 91 | 0.08 | 4.0 | - | - | - |
| | - | | No spawn | | 549 | 0.77 | 4.3 | - | - | - |
| | - | | No spawn | | 366 | 0.66 | 4.3 | - | - | - |
| | - | | No spawn | | 366 | 1.35 | 2.5 | - | - | - |
| | - | | No spawn | | 640 | 2.94 | 3.3 | - | - | - |
| | B1-B6,B8 | 4000 | 70.53 | 0.6 | 4149 | 23.97 | 2.4 | 1.04 | 0.34 | 4.00 |
| Porcher Narrows | - | | No survey | | 110 | 0.41 | 1.8 | - | - | - |
| | - | | No survey | | 91 | 0.25 | 5.5 | - | - | - |
| | - | | No survey | | 201 | 0.66 | 3.2 | - | - | - |
| Ness Is. | B1 | 430 | 1.75 | 1.0 | 549 | 0.22 | 1.0 | 1.28 | 0.13 | 1.00 |
| | B2 | 240 | 0.83 | 0.5 | 183 | 0.16 | 1.0 | 0.76 | 0.19 | 2.00 |
| | B3 | 650 | 1.40 | 0.1 | 594 | 0.36 | 1.0 | 0.91 | 0.26 | 10.00 |
| | B4 | 600 | 2.77 | 0.2 | 366 | 0.18 | 2.1 | 0.61 | 0.06 | 10.50 |
| | B5 | 680 | 6.73 | 0.3 | 549 | 1.48 | 3.8 | 0.81 | 0.22 | 12.67 |
| | B6 | 400 | 1.39 | 0.9 | 366 | 0.33 | 1.3 | 0.92 | 0.24 | 1.44 |
| | B1-B6 | 3000 | 14.87 | 0.5 | 2607 | 2.73 | 2.6 | 0.87 | 0.18 | 5.20 |

Table 4 (cont'd)

| Location | Transects | Diver | | | Fishery Officer | | | F.O.-Div-1 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Length (m) | Area (ha) | Layers | Length (m) | Area (ha) | Layers[a] | Length | Area | Layers |
| Freeman Pass | - | No spawn | | | 183 | 0.42 | 8.0 | - | - | - |
| | - | No spawn | | | 46 | 0.06 | 3.0 | - | - | - |
| | - | No spawn | | | 91 | 0.08 | 3.0 | - | - | - |
| | - | No spawn | | | 69 | 0.12 | 8.0 | - | - | - |
| | (B14) | 170 | 1.30 | 3.8 | 64 | 0.12 | 8.0 | 0.38 | 0.09 | 2.11 |
| | B14 | 260 | 1.22 | 3.8 | 69 | 0.10 | 3.0 | 0.27 | 0.08 | 0.79 |
| | (B14) | 210 | 1.28 | 3.8 | 91 | 0.16 | 5.0 | 0.43 | 0.13 | 1.32 |
| | B13 | 330 | 3.85 | 0.9 | 137 | 0.25 | 6.0 | 0.42 | 0.06 | 6.67 |
| | B10-B12 | 800 | 7.88 | 0.6 | 550 | 6.04 | 4.1 | 0.69 | 0.77 | 6.83 |
| | B9 | 270 | 1.95 | 6.0 | 274 | 0.38 | 3.0 | 1.01 | 0.19 | 0.50 |
| | B7,B8 | 710 | 6.12 | 0.2 | 457 | 0.82 | 2.8 | 0.64 | 0.13 | 14.00 |
| | B6 | 110 | 1.03 | 0.8 | 69 | 0.06 | 2.8 | 0.63 | 0.06 | 3.50 |
| | (B6) | 140 | 1.24 | 0.8 | 137 | 0.12 | 1.9 | 0.98 | 0.10 | 2.38 |
| | B5 | 530 | 6.23 | 1.1 | 219 | 0.39 | 1.9 | 0.41 | 0.06 | 1.73 |
| | B2-B4 | 1270 | 16.70 | 0.3 | No report | | | - | - | - |
| | - | No spawn | | | 914 | 1.65 | (4.1) | - | - | - |
| | B2-B14 | 4800 | 48.80 | 1.0 | 3370 | 10.77 | 4.1 | 0.70 | 0.22 | 4.10 |
| Billy Is. | B1,B2 | 460 | 1.54 | 0.7 | 91 | 0.16 | 2.0 | 0.20 | 0.10 | 2.86 |
| | B4,B5 | 170 | 0.78 | 1.0 | 110 | 0.20 | 3.0 | 0.65 | 0.26 | 3.00 |
| | B11 | 380 | 2.66 | 0.5 | 137 | 0.37 | 2.0 | 0.36 | 0.14 | 4.00 |
| | B6-B8,B12 | 790 | 3.72 | 0.6 | 201 | 0.36 | 2.0 | 0.25 | 0.10 | 3.33 |
| | B1-B12 (except B3,B9,B10) | 1800 | 8.70 | 0.7 | 539 | 1.09 | 2.2 | 0.30 | 0.13 | 3.14 |
| Totals | | | | | | | | | | |
| Portland In. | | No survey | | | 8560 | 1.89 | 0.3 | - | - | - |
| Chatham Sound | | 14100 | 157.23 | 1.1 | 19100 | 118.48 | 2.4 | 1.35 | 0.71 | 2.18 |
| North Porcher | | 5800 | 19.84 | 0.7 | No survey | | | - | - | - |
| Kitkatla Inlet | | 13600 | 142.90 | 0.7 | 10866 | 39.22 | 2.9 | 0.80 | 0.27 | 4.14 |
| All dual surveys | | 27700 | 310.13 | 0.9 | 29765 | 157.04 | 2.5 | 1.07 | 0.51 | 2.78 |
| All North Coast | | 33500 | 329.97 | 0.8 | 38516 | 159.59 | 2.5 | - | - | - |

[a]Layers for totals weighted by reported area.

FIGURES

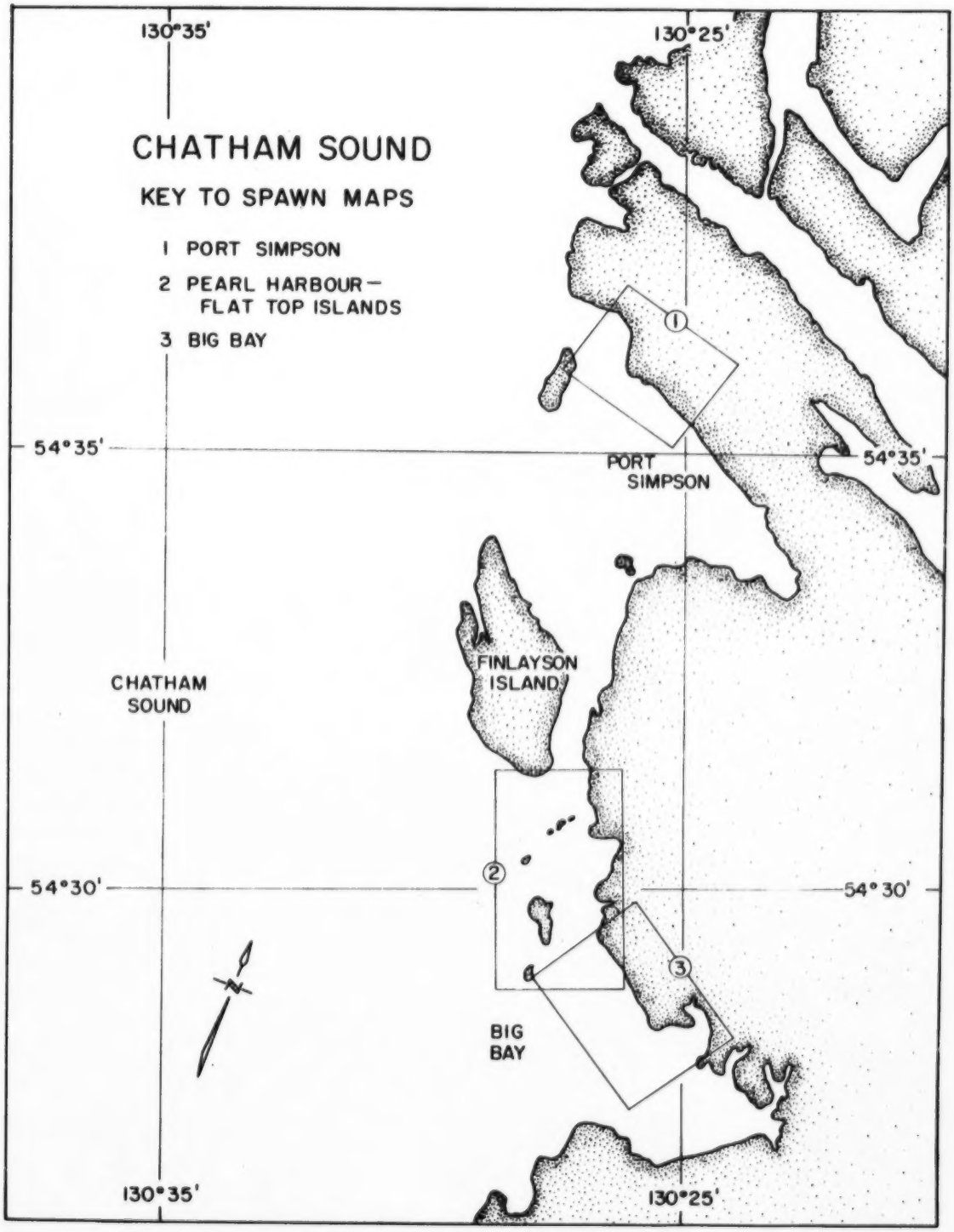


Figure 1. Map of Chatham Sound study area.

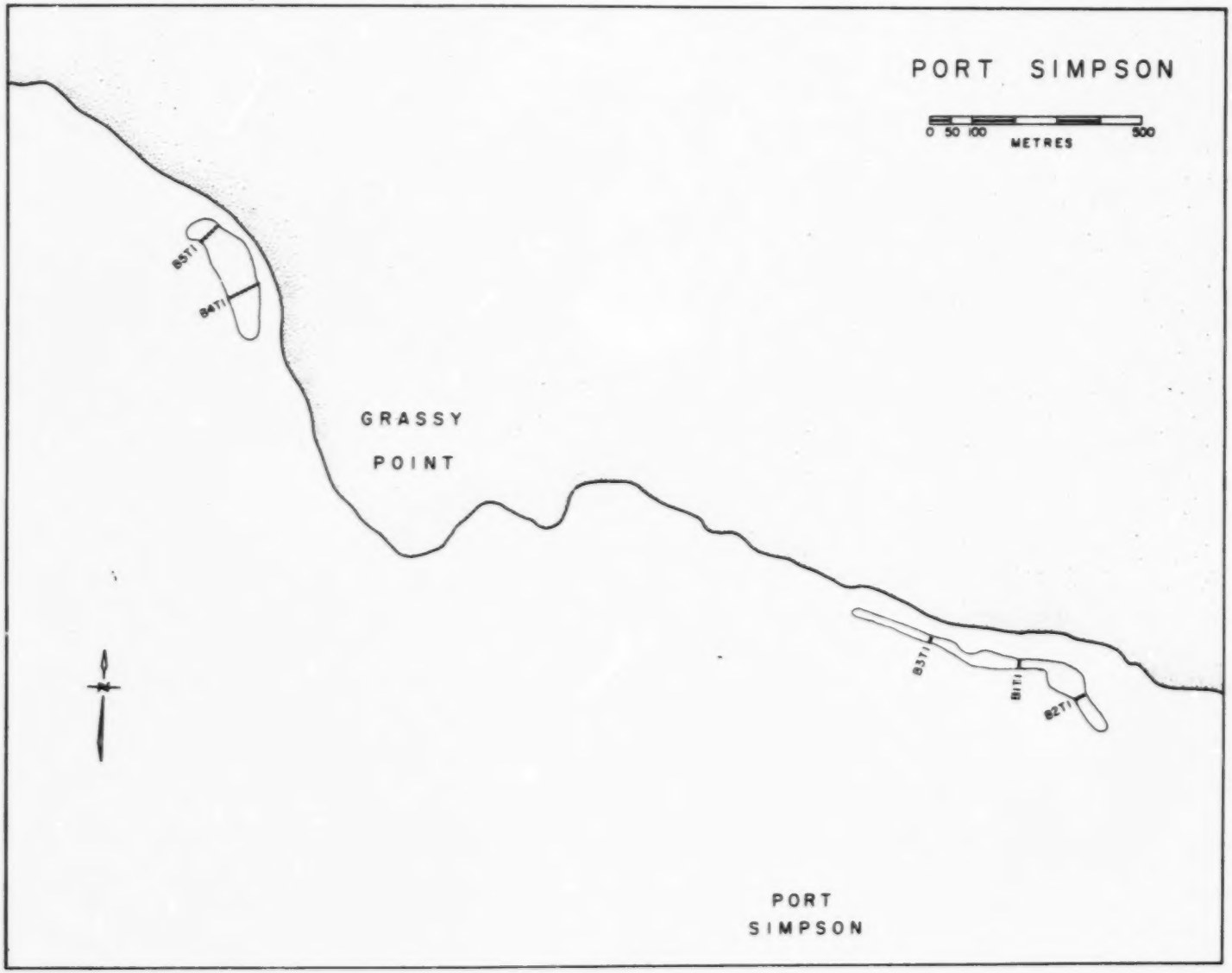


Figure 2. Herring spawn in 1982 in Port Simpson, with transects and quadrat sample sites indicated.

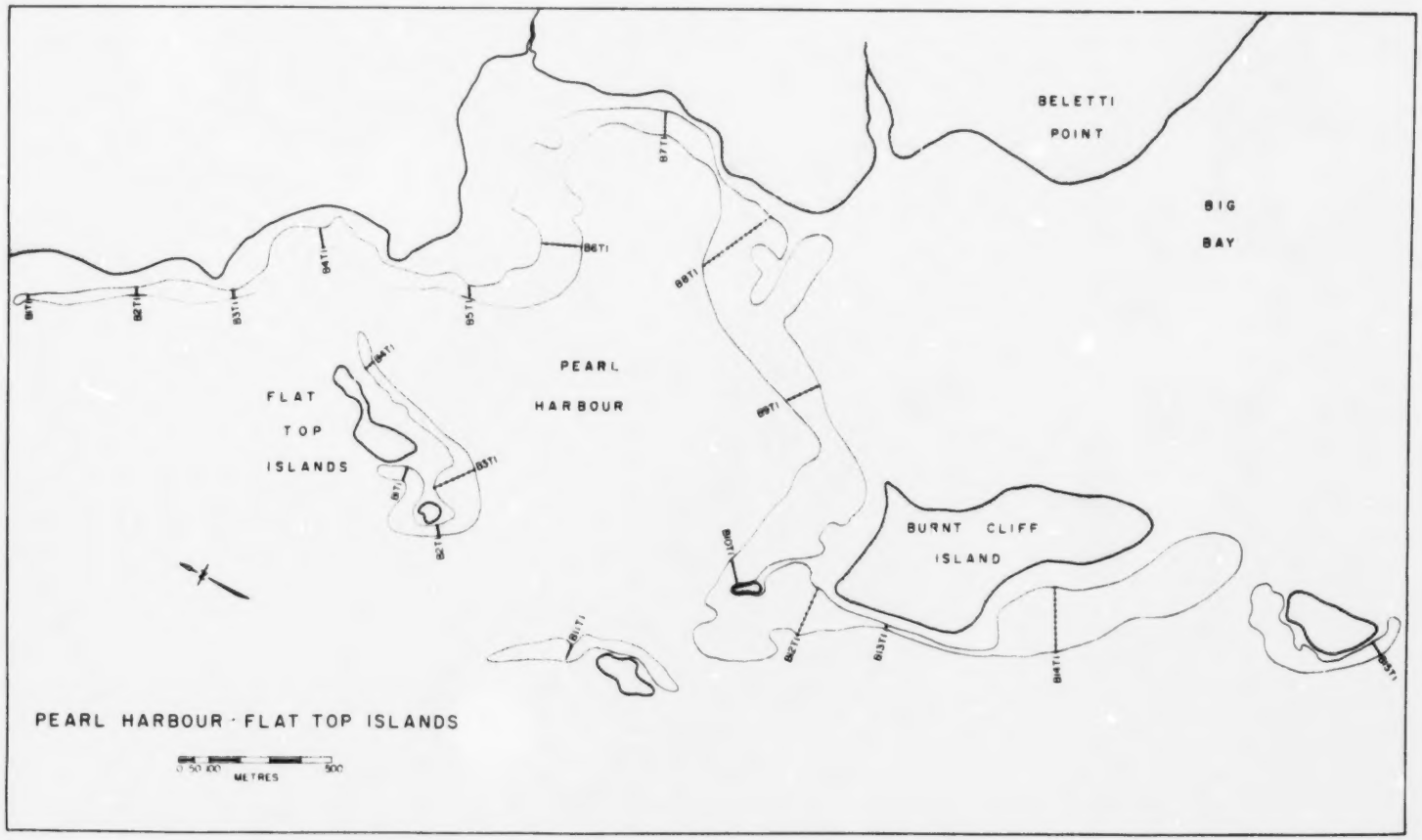


Figure 3. Herring spawn in 1982 in Pearl Harbour and around the Flat Top Islands, with transects and quadrat sample sites indicated.

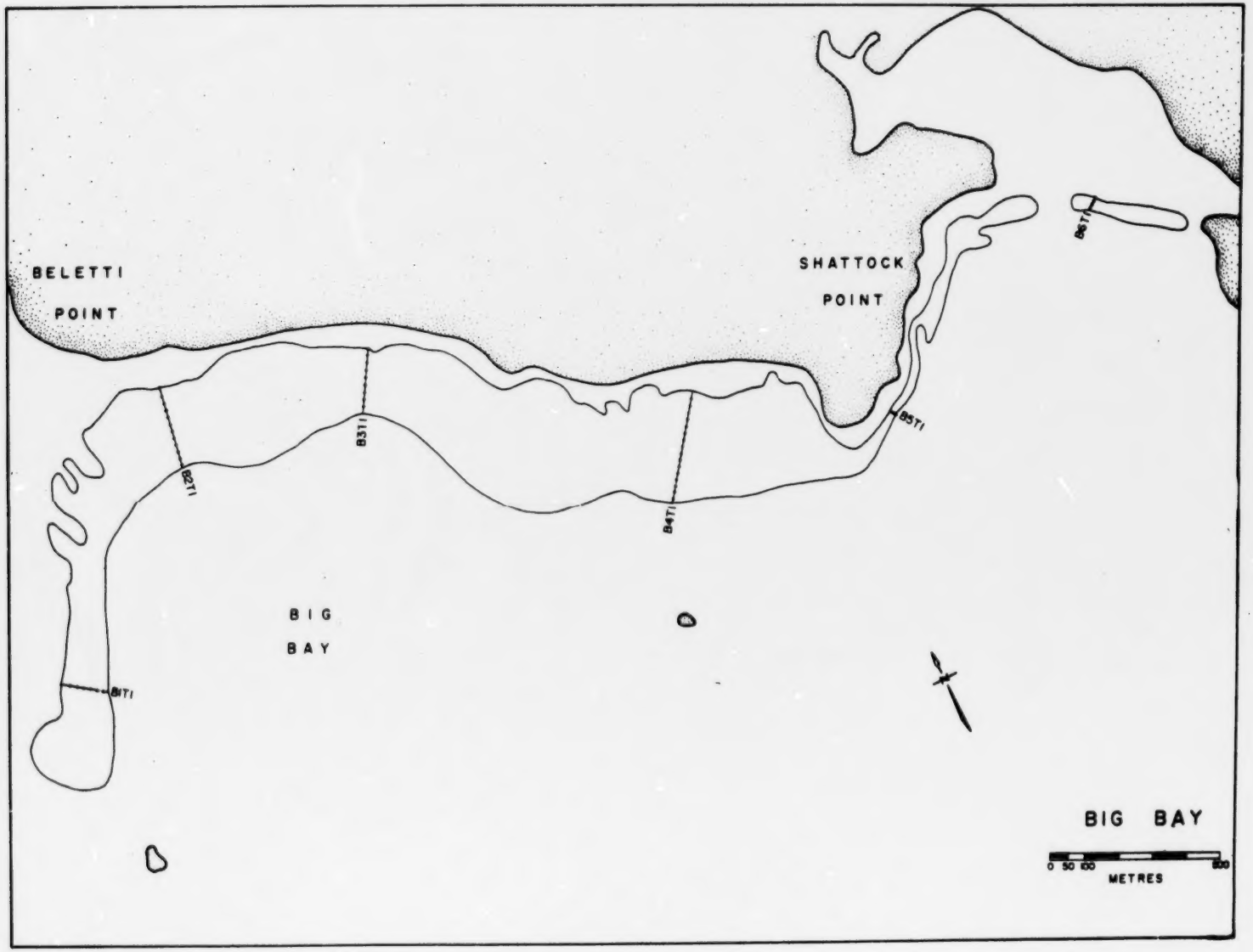


Figure 4. Herring spawn in 1982 in Big Bay, with transects and quadrat sample sites indicated.

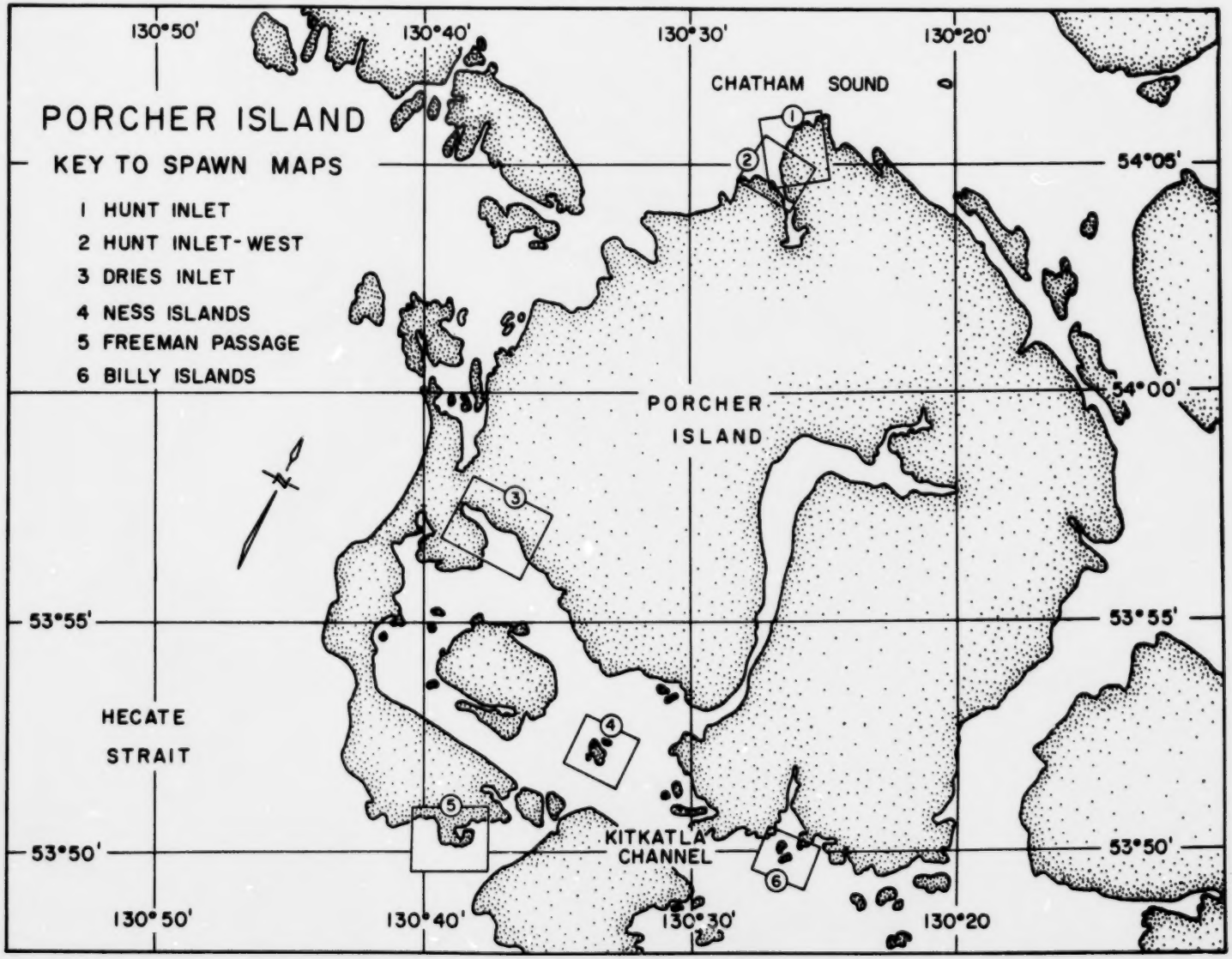


Figure 5. Map of Porcher Island study areas.

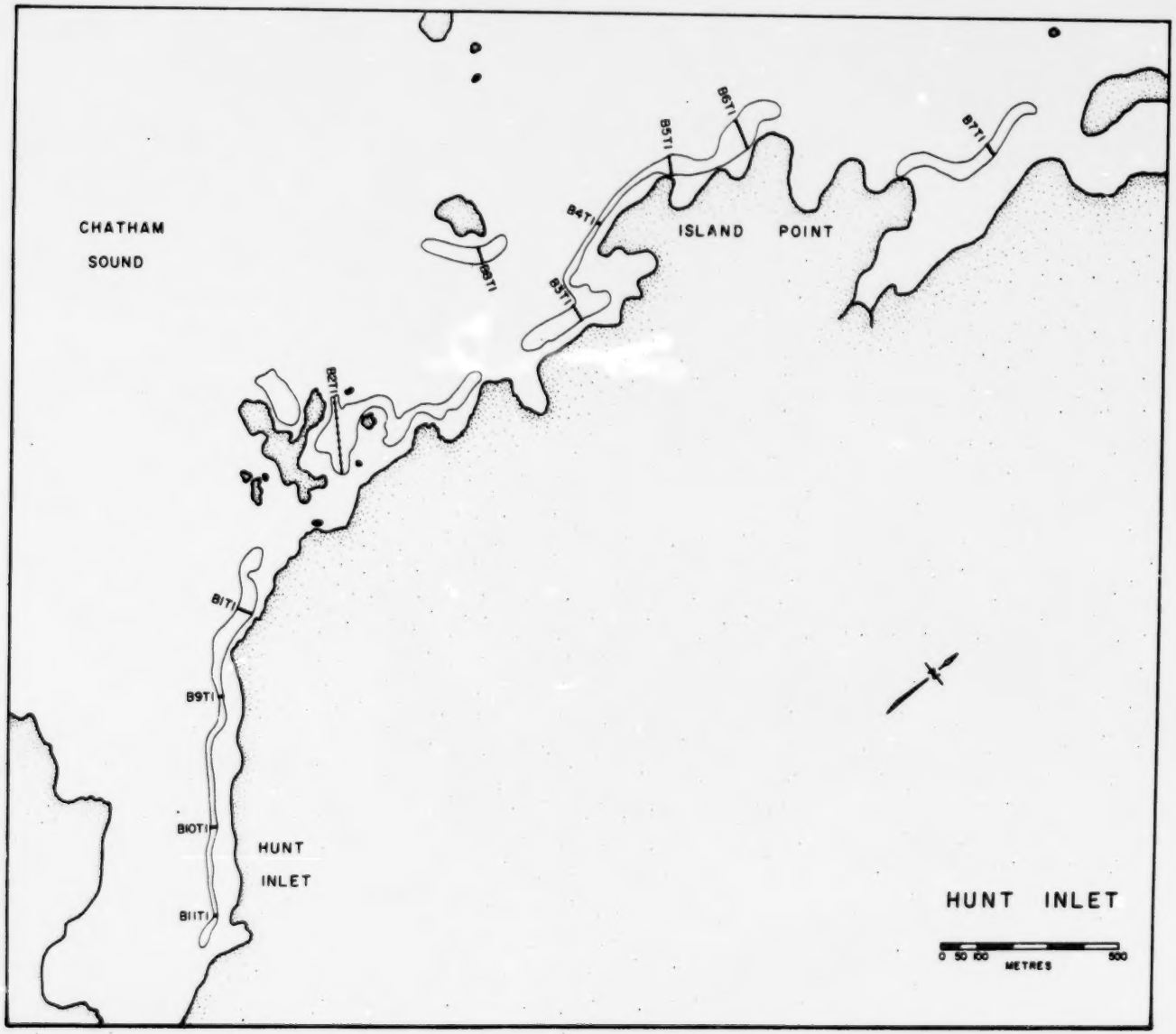


Figure 6. Herring spawn in 1982 in Hunt Inlet, with transects and quadrat sample sites indicated.

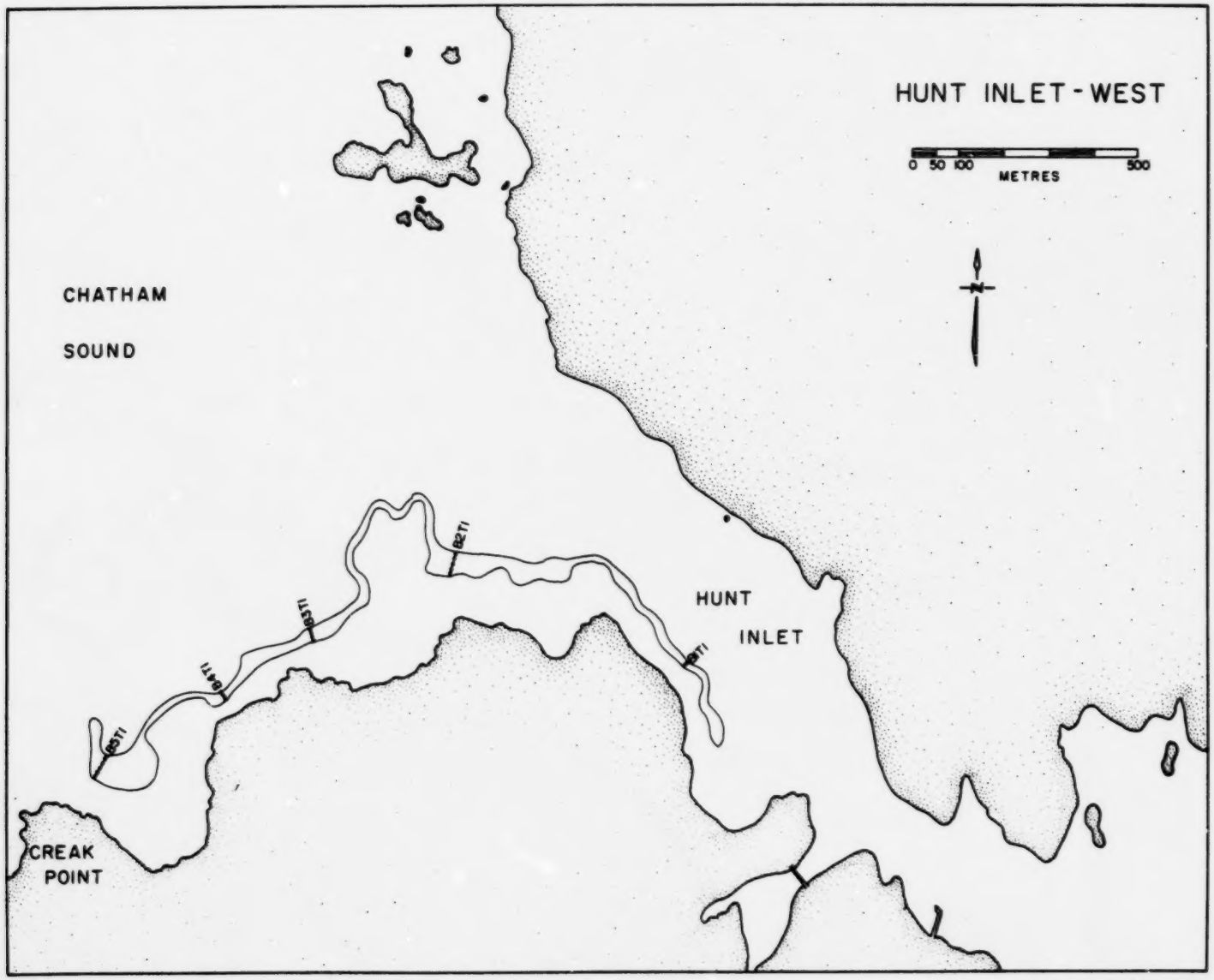


Figure 7. Herring spawn in 1982 in Hunt Inlet-West, with transects and quadrats sample sites indicated.

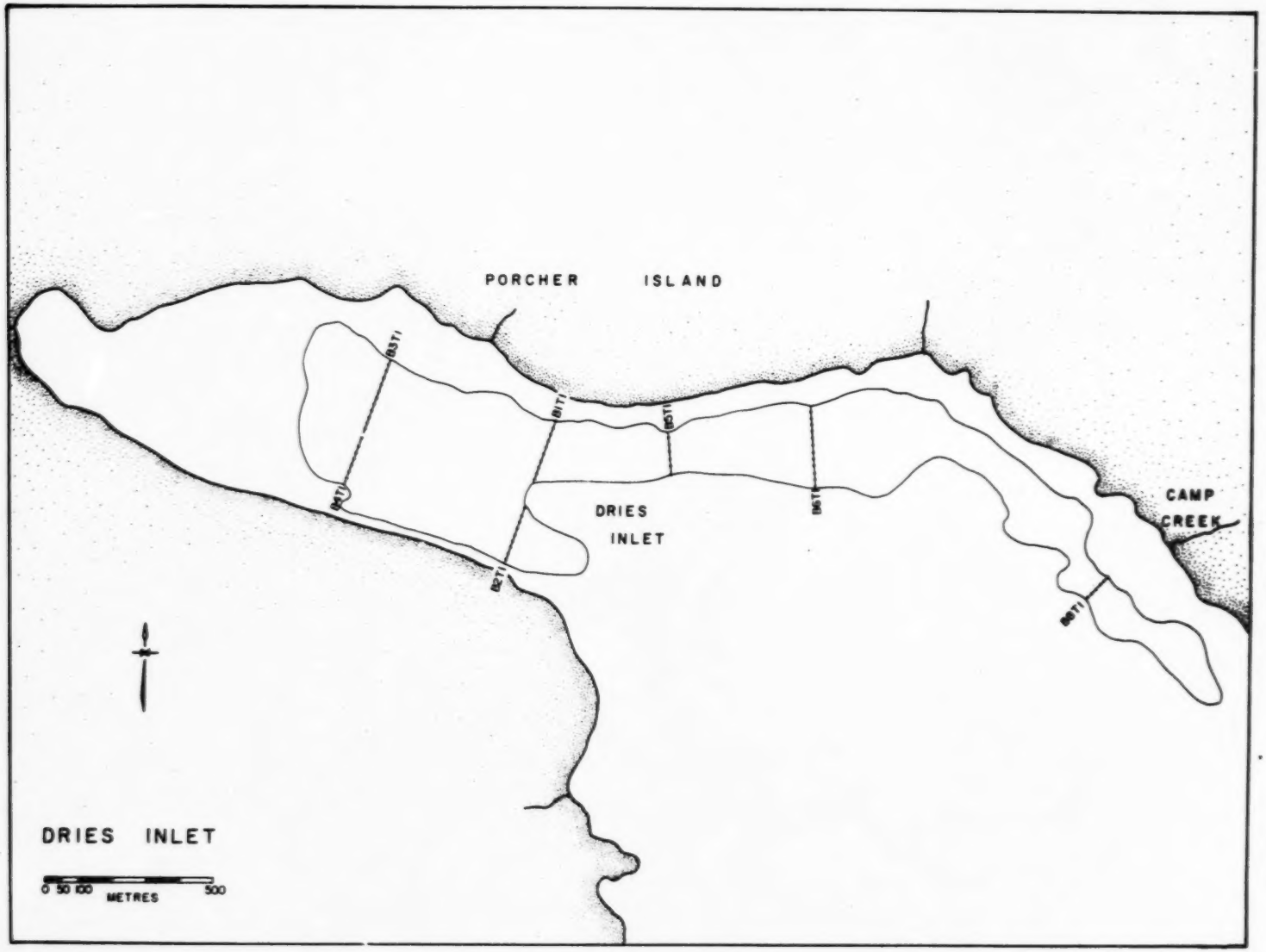


Figure 8. Herring spawn in 1982 in Dries Inlet, with transects and quadrat samples sites indicated.

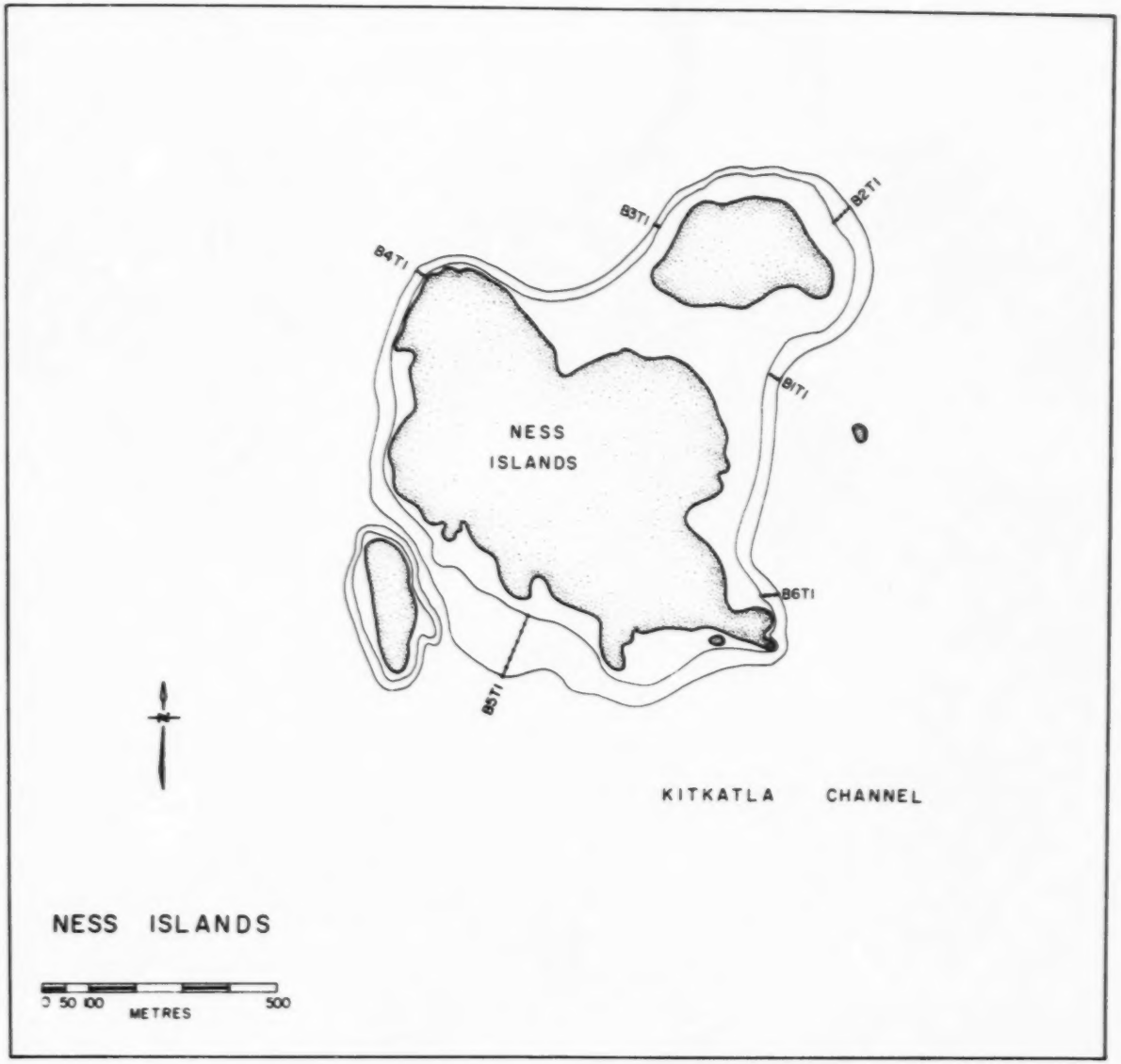


Figure 9. Herring spawn in 1982 around Ness Islands, with transects and quadrat sample sites indicated.

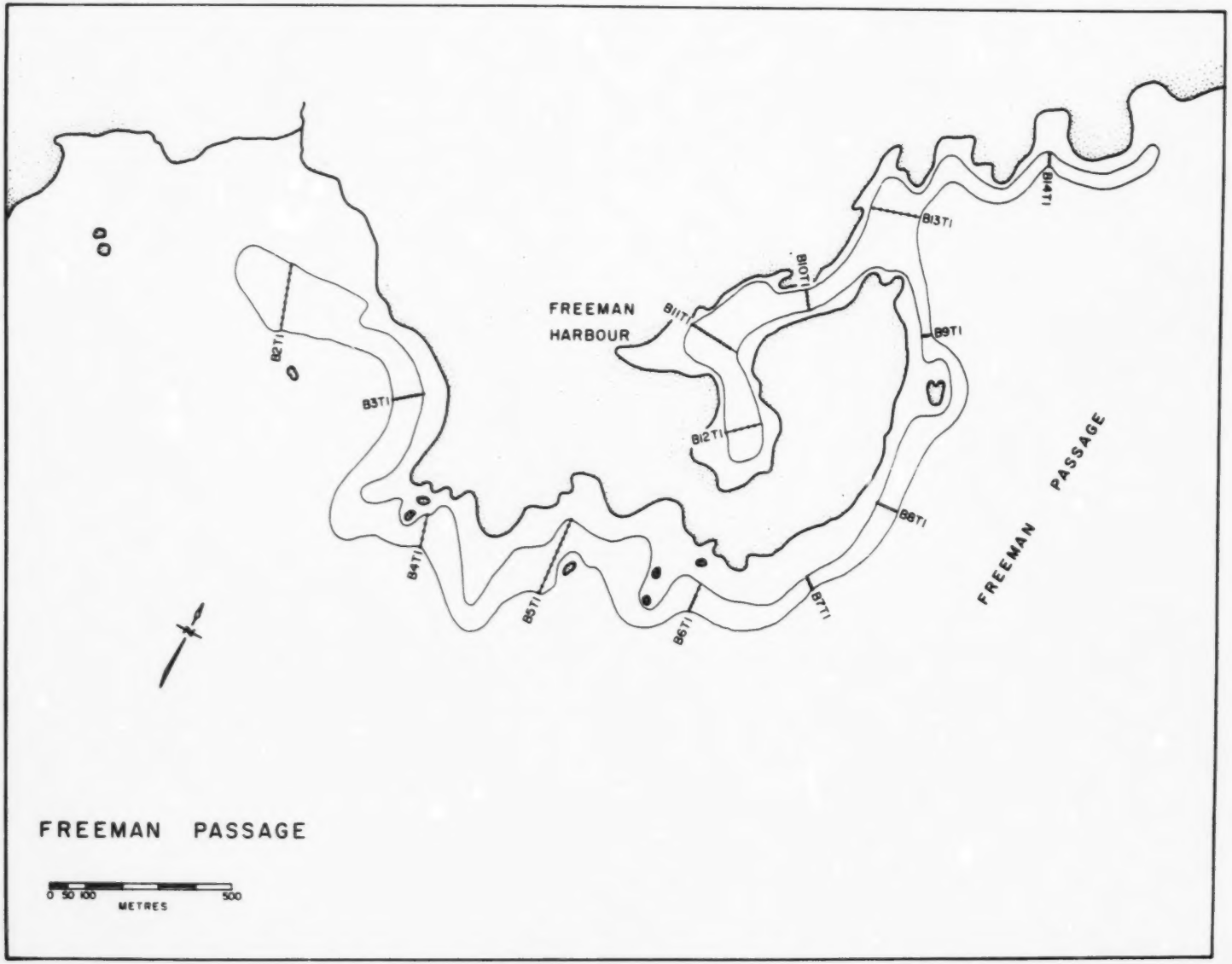


Figure 10. Herring spawn in 1982 in Freeman Passage, with transects and quadrat sample sites indicated.

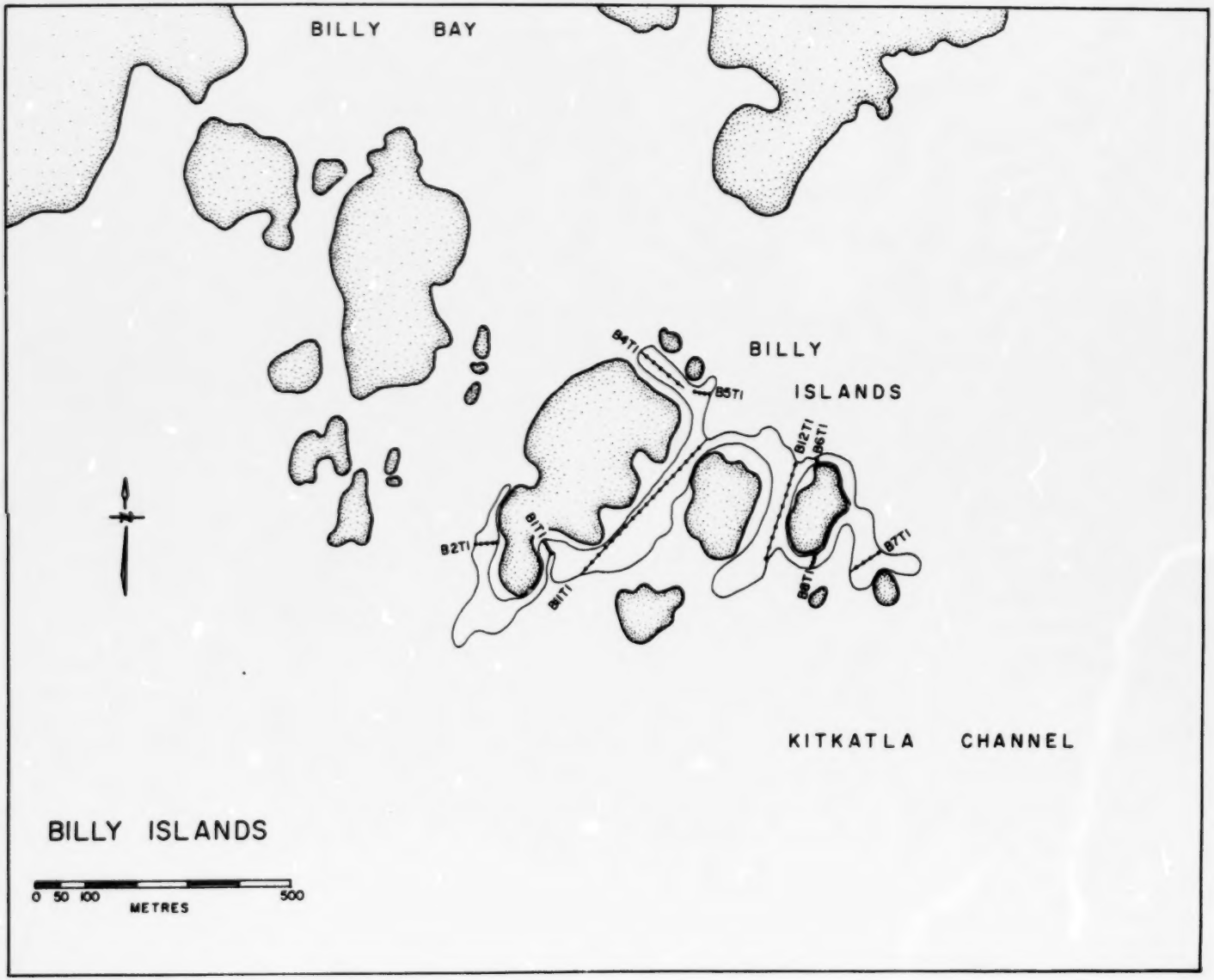


Figure 11. Herring spawn in 1982 around Billy Islands, with transects and quadrat sample sites indicated.

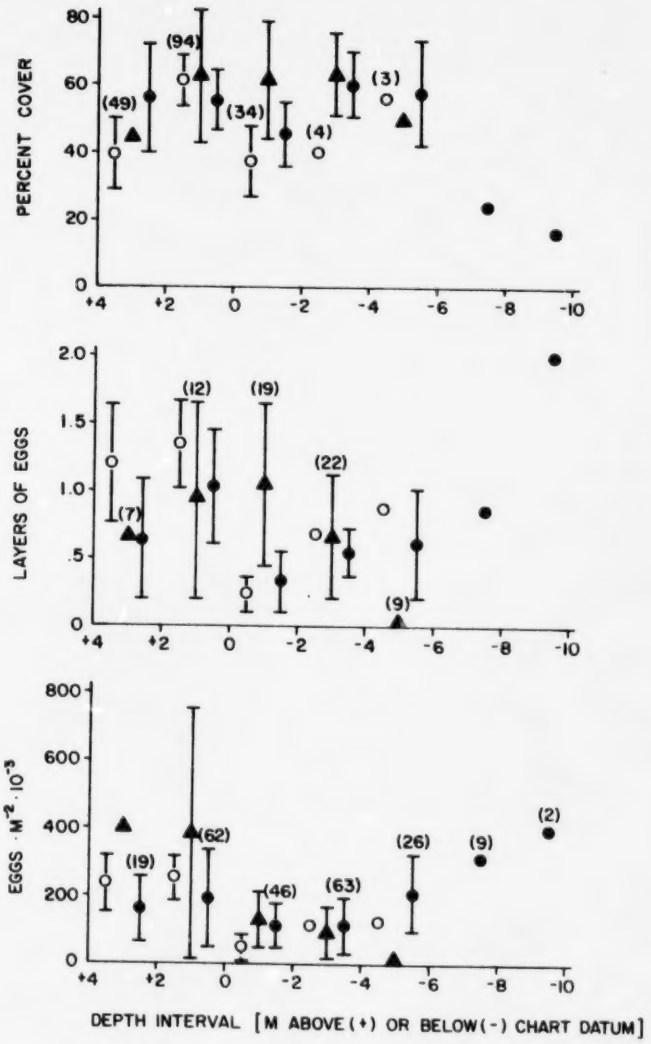


Figure 12. Average percent cover of vegetation, layers of eggs, and egg density (±2SE) by 2 m depth interval for Chatham Sound (open circles), North Porcher Island (triangles) and Kitkatla Inlet (closed circles) spawns.

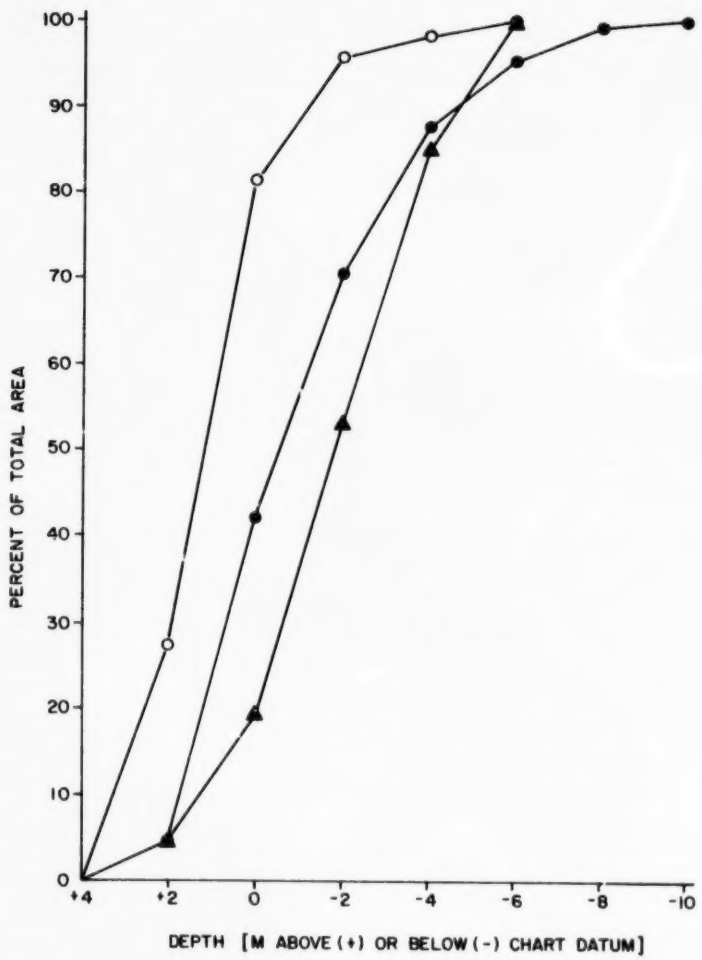


Figure 13. Distribution of spawn area by depth for Chatham Sound (open circles), North Porcher Island (triangles), and Kitkatla Inlet (closed circles).

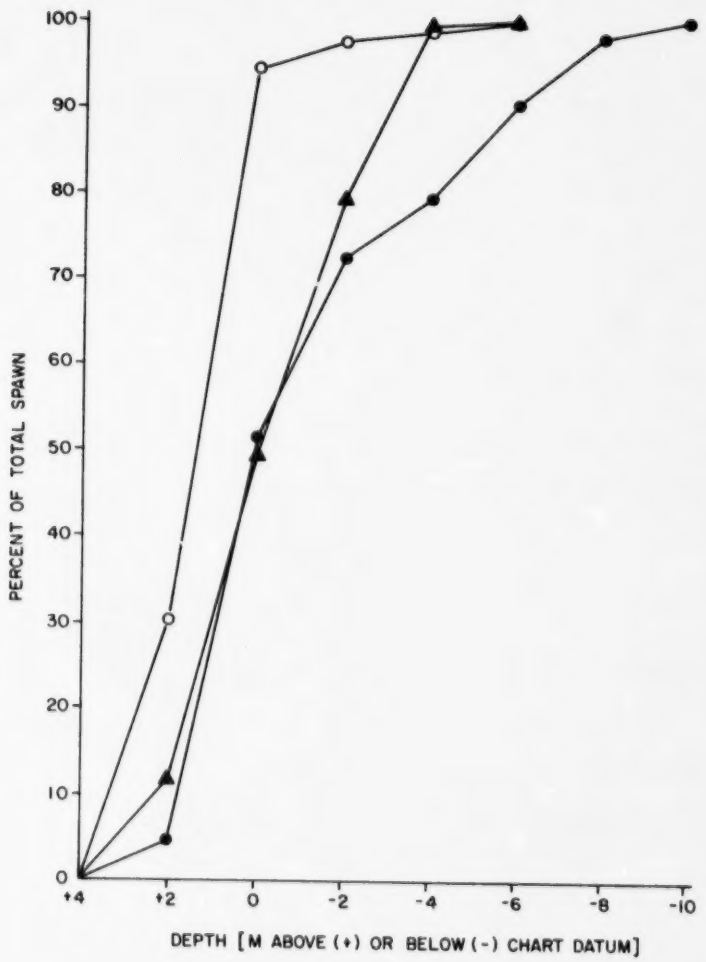


Figure 14. Distribution of eggs by depth for Chatham Sound (open circles), North Porcher Island (triangles), and Kitkatla Inlet (closed circles).